CHAPTER 19

CONSTRUCTION

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19.1 OVERVIEW

19.1.1 Introduction

In most Agencies, different personnel perform the design and construction functions. Adequate communication between the two is essential. Design personnel should be aware that there are construction-related design considerations, and construction personnel should be aware that there are design-related construction considerations. Thus, it is very important to have good communication between design and construction personnel.

When problems arise, they should be discussed and a workable solution decided upon. A forum for design-construction related discussion sessions should be provided on a regular basis. Redundancy and adherence to archaic methodology could be overcome by using this forum to develop solution(s) and utilize expertise from both functions. Primarily, these sessions would be at pre-construction stage or the post construction conference.

Open communication between design and construction personnel should lead to good working relationships. These relationships will help improve designs and ensure that projects are constructed as envisioned without causing major problems or field revisions.

19.1.2 Construction Considerations

Construction-related hydraulic considerations are a necessary part of the planning and design phases. Factors that will affect construction timing and methods need to be considered as project development proceeds. Those responsible for contract administration and actual construction may need to coordinate their scheduling and construction procedures with the designer to achieve the results intended. Any special or unique construction requirements should be communicated to the designer prior to the final design phase of the project.

The designer should be present at the preconstruction conference to explain special features and planned construction phasing where these considerations are necessary to the proper functioning of the design. It may be advisable and necessary to specify certain time limits and special instructions on how the work will be accomplished. Phased construction to accommodate seasonal variations, floods, fish passage and irrigation may be needed. In addition, the need for special considerations related to needed temporary work, detours and public safety issues can be outlined and discussed. It should be emphasized by the designer that any and all revisions of drainage designs as contained on construction plans should be discussed with the designer prior to execution.

19.1.3 Cost Considerations

Cost is an important consideration in any design. The primary components of first costs are related to materials and construction. Future maintenance/replacement costs are an important related design consideration. The designer must achieve the proper balance of material, construction and maintenance/replacement costs.

Ordinarily, material costs are optimized by using available materials in a consistent manner; recycling materials; researching programs to identify potential construction materials and how they may be utilized efficiently; using reasonable safety factors in design; and encouraging and allowing alternatives where possible. In some cases, the least expensive material may not be the proper choice because construction costs are greater than for a more expensive material or

future maintenance/replacement costs override the material costs advantage. For example, geosynthetics may be an advantageous alternative to granular filter materials in some situations.

Construction costs are affected by the:

- Project's schedule;
- Location;
- relative difficulty of construction;
- laws, rules and/or regulations governing construction procedures;
- degree of competition among contractors;
- construction latitude allowed by the specifications;
- degree of use of standardized construction details and specifications;
- quality of the construction plans; and
- degree of supervision and inspection provided by the Department.

The choice of a more complicated and expensive construction procedure may be proper if it allows the use of more economical materials, decreases maintenance costs and eliminates or reduces the need for replacements.

19.1.4 Construction Plans

The designer must be aware of the above relationships and how they affect costs and consider them in design. Additionally, construction plans should reflect these considerations by containing:

- suggested construction sequences that consider construction costs, environmental considerations and public convenience;

- subsurface soil borings;

- detour plan;

- quality control plan;

- complete descriptions of utilities; and

- consistent plan format that enhances the contractor's ability to assimilate and understand the Department's plans.

Despite the best of efforts, construction changes occasionally occur. The designer should be consulted when these changes may affect the proper functioning of the drainage facilities.

The post-construction inspection following completion of the project should document any deviations from the original plans and an initial assessment of the hydraulic performance. Construction personnel should be encouraged to inform the designer of any design-related difficulties that are encountered and suggestions to improve future designs. Changes shall be incorporated into "as-built" plans for future reference.

Plans should be checked to verify that site conditions have not changed between location surveys and construction and also between location survey and preliminary plan completion.

Meander migration, bank caving, aggradation, headcutting or other natural or man-induced changes in the channel may have occurred that would require the designer to reconsider decisions made on the basis of conditions that were different from those that existed at the beginning of construction. This is best accomplished with a joint field inspection by design, construction and maintenance personnel. Additional objectives of the inspection are to assure location survey accuracy and to ascertain if the designer has properly visualized existing situations and designed accordingly.

The changed conditions may require river control works, revisions to pier locations and orientation, rearrangement of spans, or other modifications of the design to accommodate the changes that have occurred. Plan changes required because of differences between location surveys and construction field inspections should be made in consultation with the designer. Some changes could significantly affect either the hydrology or the hydraulic performance of the drainage feature designed for the site.

19.1.5 Effects of Changes

Land-use changes in the watershed can modify the hydrology and debris considerations used in the design. New development along the project could change damage risk considerations for the design. Dependent upon the time that has elapsed between completion of the design plans and the beginning of construction, changes in land use could significantly affect the validity of design considerations. Commercial mining of materials for construction is a rather common practice that can change flow velocities, volume and character of bedload and flow direction and distribution at the crossing site. Agricultural land clearing may create a need to reconsider the location and size of waterway openings and the need for spur dikes. Land development near the site could change damage risk considerations for the crossing. The designer should be consulted regarding the need to modify the design at any drainage facility site that has changed significantly from the conditions that existed during design.

Changes in stream alignment and profile can result in different flow conditions than those used in the outfall or cross drain design. Drainage area changes due to diversions or site grading can affect inlet and outlet locations and type and storm drain or roadside ditch designs.

Utilities added after the survey may require extensive redesign of storm drain systems to avoid conflicts; this reinforces the need for good utility surveys prior to design to forestall costly redesigns and delays. See Table 19-1 for an additional discussion on some typical changes that may affect drainage design.

In some cases, a considerable amount of time may elapse between design and construction. In other cases, designs may change before construction is begun. Any changes in the plans, specifications and estimates should be reflected in the final plans. If questions arise, the construction personnel should check with the designers to determine if the proposed changes are acceptable and if they are appropriately reflected in final plans.

19.2 PRECONSTRUCTION CONFERENCE

19.2.1 Introduction

It is important for the designer to be present at the preconstruction conference to explain special features of the designs and planned construction phasing, where these considerations are necessary for proper functioning of the design. It may be advisable and necessary to specify

TABLE 19-1 — Changes That May Affect Drainage Designs and Are Detectable During Field Inspection

Possible Errors or Omissions
• Incorrect existing structure and/or invert elevations; • Incorrect drainage area size; • Channel alignment, profile; • Unreported utility; • Existing structure condition as related to service life, outlet scour, siltation; • Local flooding not documented; • Existing slope erosion not reported; • Sensitive receiving waters not reported; • Unreported debris problems; • Unreported ice jams; and • Attractive nuisance problems.
Possible Changes
• Increased development, • Channel improvements, • Diversion or site grading changes, • New utility, and • Loss of outfall due to development.
Miscellaneous
• Incorrect typical section choice and/or incorrect grade.

certain time limits and special instructions on how the work will be accomplished. The designer should answer any construction-design questions that the contractor's construction personnel have or endeavor to obtain answers as soon as possible.

The designer should go over the job with several key personnel including the resident engineer, contractor's agent, right-of-way agent, traffic engineers, materials engineer, maintenance superintendent, surveyors and others who may have a direct interest in the project. Such a review at this time will aid materially in clearing up reasons for certain design features such as right-of-way obligations; signing and traffic handling difficulties; materials sites; selected material; foundation treatment; potential slides; environmental commitments; and potential drainage and maintenance problems, including erosion control and water pollution.

The purpose of the meeting is to discuss the design and construction aspects of the project, thus affording all parties a common understanding of the proposed work and the problems and possible solutions that may be expected.

19.2.2 Other Concerns

Several other concerns should be discussed at the preconstruction conference including drainage maintenance during construction, water pollution, erosion control and permit requirements and penalties.

Drainage work on some projects may be completed several months before total project completion. During this period, vegetative erosion control measures are not well established and maintenance to correct erosion and sediment deposition in the newly constructed channels is important to achieving the results intended. The Department should provide for maintenance by the contractor during the term of the contract, require interim protective measures, and/or advance its own maintenance schedule to assure that minor damage will not develop into major damage that will require costly repairs or replacement when it assumes the permanent maintenance responsibility.

During the preconstruction conference, provisions of the contract relating to pollution control should be reviewed. Prior to beginning work, the contractor may be required to submit a pollution prevention plan to control water pollution (or the Department should waive the specified requirement if such action is in order).

19.3 CONSTRUCTION CONSIDERATIONS

19.3.1 Introduction

Problems may be avoided during construction when important drainage or other water-related factors are considered during the location and planning phases of the project. If possible, problem locations should be avoided. A site may be considered a problem location because of geological aspects, environmental concerns, other existing facilities or other reasons that might conflict with the proposed project.

The concerns of erosion and sediment, where they might occur and how to control them, must be considered, at least in broad terms, during the early phases of location. As an example, the designer may be involved in the geological investigations because of underground water so that proper measures can be taken to prevent problems before they occur.

The erosion and sediment control procedures are explained in detail in Section 19.5.

The time of the year and total construction time should be considered. Certain elements (e.g., embankments along a stream) should be completed before the anticipated flood season. In some areas, work cannot be performed in the streams during fish spawning runs. In other areas, the stream may be an irrigation supply and flows cannot be interrupted nor can the pumping and distribution system be contaminated with sediment.

The use of temporary structures must also be planned. Often a temporary crossing is smaller than the permanent drainage structures. The design of the temporary structures must be reviewed and accepted by Department. More information on design conditions for temporary structures can be found in Section 19.7 and in Appendix 19.A.

Construction activities in a coastal zone or in the area of a large lake or reservoir may also present unique problems that need to be considered. Fluctuations in the water level due to waves or tidal action along a coastline; floods resulting from upland runoff in combination with

the tides and waves; or fluctuations in reservoir level due to water management and power generation may require special construction techniques such as dewatering or underwater works in these areas. Other issues such as access to the site, on-site storage of construction materials, time of year restrictions and sequence of constructions may also warrant special considerations.

Many construction-related hydraulic problems are related to scheduling. Although these problems will be studied in more detail during the design phase, they should be initially considered, at least in a preliminary manner, as early as possible. Commitments regarding water resource related items made in the Environmental Impact Statement (EIS) must be made known to the personnel who will be involved in the actual construction. Some commitments that "sound nice" may not be feasible to build. In other cases, construction occurs so long after the EIS has been prepared that those commitments are forgotten or not included in the plans or contract documents. A "commitment list" that follows the project through the various stages of development should be prepared to ensure that these items are, in fact, incorporated into the project.

19.3.2 Environmental Concerns

The designer can work with other disciplines to devise and construct mitigation measures that reduce adverse effects. The designer can recommend locations and sizes for hydraulic facilities (e.g., for culverts, bridges, channels) and identify spoil disposal areas and geometry and various construction alternatives. The designer may also assist in developing programs for protecting surface waters during construction including but not limited to:

- levees and ponds to collect various types and quantities of pollutants including those from construction equipment or which are accidentally spilled,
- methods to reduce erosion and sedimentation, and
- replacement methods of surface waters that assimilate the hydrologic and hydraulic regime of those that are affected.

More information on these programs can be found in Chapters 15 and 16 of this *Manual* and in Chapters 3 and 10 of Reference *(1)*.

19.4 HYDROLOGY

19.4.1 Low-Flow Discharge

Construction and maintenance of highways may require knowledge of low-flow discharge properties (e.g., discharges, flow stages, flow durations, related flow variables). For example, the construction of a culvert or a bridge may require knowledge of the time frame at which flows are below certain levels or below certain magnitudes. This knowledge might be useful in scheduling construction or designing temporary construction facilities. With some facilities, it is often necessary to avoid long periods where the facilities are unavailable to the user due to prolonged occupation of a portion of the facility by frequent low flows.

19.4.2 Timing and Risk

Annually, USGS publishes "Water Resources Data" for gaged streams listing mean daily discharge. Based on these daily records, a low-flow analysis may determine an acceptable discharge for the hydraulic design of temporary construction facilities. A rigorous flood frequency analysis is not generally required for these low-flow studies. Flow discharges may be cursorily determined based on a visual examination of monthly mean discharge data as determined from the mean daily discharge values for all years of record and with consideration to construction timing and degree of risk. Data for the monthly mean discharge may be obtained from the local USGS field office or on the USGS web site for surface water statistics for Utah at *http://waterdata.usgs.gov/ut/nwis/sw*.

Acceptable methods that can be used to transfer data from one location to another and hydrologic regression equations are given in the Hydrology Chapter of this *Manual*.

If hydrographs or other hydrologic data or temporary structure sizes are furnished to the contractor or included in the plans for the contractor's use in planning and scheduling operations, the contract documents should indicate that the plots or data are for information only and that the Department assumes no responsibility for conclusions or interpretations made from the records.

19.4.3 Water Quality

Water quality of streams and lakes has become a very sensitive issue. Drainage construction may deliver such things as sediment and chemicals to streams, rivers and lakes unless precautions are taken. Annual runoff hydrographs may indicate that very low stream flows will occur during the late fall and winter months. During these periods, even small amounts of additional sediment or chemicals entering the stream from construction areas could be detrimental because of the low dilution effect provided by the receiving waters. The effects of sediment or chemicals due to highway construction during the low-flow periods should be investigated for those sensitive areas (e.g., where stream flow is used for municipal water supply). This investigation may include periods of water quality monitoring and testing. If the investigation concludes that the amount of sediment or chemicals will exceed an acceptable threshold value, the construction periods may have to be rescheduled or mitigation measures taken. The stream flow and water quality may also require monitoring, if the groundwater or water from the stream is being removed for construction purposes.

19.5 EROSION AND SEDIMENT CONTROL

19.5.1 Construction

By the time construction begins, all erosion and sediment control considerations made during the planning, location and plan development phases should be contained in the plans, specifications and special provisions provided to the contractor and Department personnel for accomplishment of the project construction.

The resident engineer and his inspection staff should thoroughly familiarize himself and the inspection staff with the erosion and sediment sensitive areas of the project and with the control measures contained in the plans. This information should be shared with the contractor for his formulation of a work plan.

The contractor should utilize an erosion and sediment control schedule that sets forth the proposed construction sequences and the erosion control measures that will be employed. This schedule allows the contractor and engineering personnel to plan ahead and control erosion and sediment before it becomes a problem rather than adding measures after damages have occurred.

Adequate inspection during construction is essential for erosion and sediment control. If deficiencies in the design or performance of control measures are discovered, the resident should take immediate steps for correction, including notification of the designer to avoid a recurrence of the problem.

Periodic field reviews and inspections by the design and resident engineers to correct deficiencies and improve control procedures is highly recommended.

FHWA requests that erosion and sediment control shall follow the procedures described in Chapter 3 of Reference *(1)* for Federal-aid projects.

19.5.2 Construction Feedback

An important consideration in the decision to utilize any erosion or sediment control measure is its effectiveness in the particular circumstances of planned use. There is no better way to answer this question than through experience. For this reason, it is very critical to the development of a good erosion and sediment control program that communication exists between design and construction personnel. One method of establishing communication is to have regularly scheduled project field reviews or meetings involving those responsible for design and construction. During these meetings, problems and successes with particular items can be evaluated. Different ideas and procedures that have been successfully employed by a contractor can be studied to determine if they warrant consideration for widespread use. Also of importance for discussion is possible modification to standard design items that would facilitate their construction and/or perhaps reduce their cost.

This feedback procedure extends beyond construction into the long-term maintenance of erosion-related items. Maintenance personnel must check and correct any deficiencies in the permanent erosion control measures. Design personnel should be apprised of any persistent problems so that an analysis can be made to determine if any alteration of design or construction practices is warranted to reduce maintenance problems.

19.5.3 Other Considerations

For a complete discussion of other considerations related to erosion and sediment control, see Chapter 16 “Erosion and Sediment Control.”

19.6 CULVERTS

19.6.1 Preparation

The plans, specifications and other construction documents should be reviewed to ensure that the design fits current site conditions. Design personnel should be informed and involved in all changes to the plans and specifications.

As soon as final locations are determined, furnish the contractor a revised culvert list, including those culverts that have been added or altered by change order.

19.6.2 Installation

Assembly or fabrication, bedding and backfill and scour protection are as important to culvert service as the hydraulic and structural design.

Culverts should be protected from damage during construction operations and should be periodically inspected. A particularly critical time for inspection is upon completion of grading operations and prior to the start of surfacing operations. Another critical time for inspection is after the installation of the culvert and prior to backfilling. It is as important to inspect culverts that are not under the roadway as it is for those structures that are under the roadway. Prior to the acceptance of the installation, all culverts should be inspected and cleaned as necessary.

19.6.3 Stream Restoration

The installation, replacement or extension of a culvert typically will require minor amounts of channel work. The contractor should take sufficient measures to minimize damage to the stream outside of the construction limits as shown on the plans. Upon completion of the construction activities, the stream or channel should be restored to its preconstruction condition as practicable. The contractor should also restore or repair any area of the stream outside of the construction limits that received damage due to work activities.

19.6.4 Records

Records should be kept of the construction of each culvert installation. The final location and slope of the culvert should be recorded on the “as-built” plans (see Section 19.10). This information is useful for evaluating overall performance of the installation.

The following records should be kept for each installation:

- special features, such as:
    - fishways,
    - improved inlets,
    - debris protection, and
    - energy dissipators;
- location and layout including:
    - station;
    - skew(s);
    - location of inlets, outlets, junctions;
    - flowline elevations in inlets, outlets, junctions;
    - camber;
    - alignment; and
    - grade;
- daily reports;

- structure summary sheet containing:

    - measurements;
    - fishway, if any; and
    - calculations and pay quantities.

19.7 BRIDGES

19.7.1 Hydraulic Considerations

The responsibility for construction-related hydraulic considerations of bridge construction ordinarily rests with the contractor but, in some cases, the Department may include construction-related details in the plans and specifications to mitigate potential environmental effects or to assume or reduce the risk of failure during construction. In addition, other special provisions related to the construction phase of the bridge construction may be specified in the plans. Whether the Department or the contractor assumes the risk and responsibility, hydraulic considerations during construction usually differ from the design considerations for the completed facility.

19.7.2 Hydrologic Information

A hydrograph of superimposed mean daily flows and a plot of the rating table for a stream-gaging station near the crossing site are useful for the design of cofferdams, falsework and temporary crossings, in Department scheduling of the work and in selecting the location of work and material storage areas. If the hydrograph is furnished to the contractor or included in the plans for the contractor's use in planning and scheduling operations, the contract documents should include that the plot is for information only and that the Department assumes no responsibility for conclusions or interpretations made from the records.

In the event a gaging station is not located near the stream crossing site, records from upstream or downstream gages may be useful as an indication of the usual magnitude, duration and time of flood events.

19.7.3 Foundation and Scour

Any site conditions that might impact the foundation design or create unusual scour problems should be discussed with design personnel to determine if design changes are indicated. If specific elements of the bridge design are dependent on special foundation or scour considerations, construction personnel should be informed so that they can identify possible problems.

19.7.4 Cofferdams, Caissons and Falsework

Cofferdams, falsework and occasionally contractor's equipment (e.g., barges) constrict the stream channel more than the completed substructure and consequently have greater potential for causing scour and bank caving and for collecting debris. Scheduling of work to avoid flood seasons is especially important if these types of operations will be involved.

19.7.5 Crossings and Detours

Temporary stream crossings necessary for the construction of bridges are usually the responsibility of the contractor. It may be desirable in some instances, however, for the Department to design such crossings to minimize or mitigate the adverse effects on the stream environment, to facilitate securing permits or to reduce the risk assumed by the contractor and thereby reduce construction costs.

In addition, stream crossings for detours are built to much lesser standards than permanent crossings. The criteria used for the hydraulic design of detour stream crossings should be based on risk factors that should be evaluated considering the probability of flood exceedance during the anticipated service life of the detour (the construction period for the crossing), the risk to life and property and traffic service requirements. Figure 19-1 can be used to assist in designing temporary stream crossings and detours.

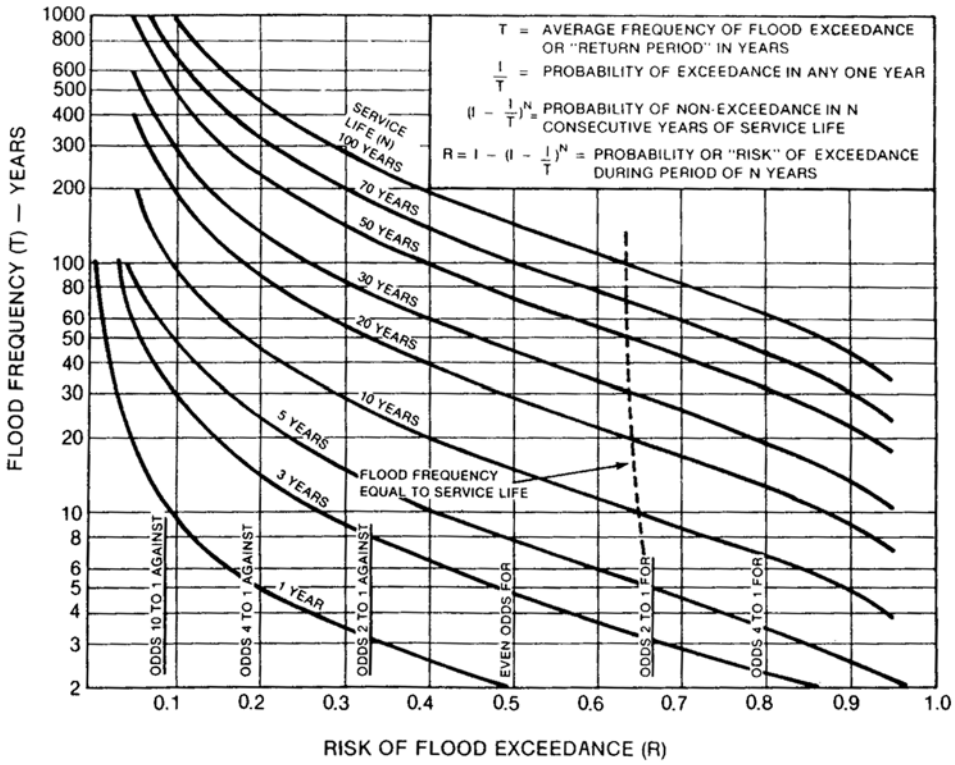

FIGURE 19-1 — Probability or Risk of Exceedance of a Flood Event vs. Service Life of a Highway Encroachment

As in the case of the design of highway stream crossings, detour designs should accommodate floods larger than the event for which they are designed to avoid undue liability for damages from excessive backwater and to reduce the probability of losing the detour stream crossing structure during a larger flood. In most instances, the conveyance of floods larger than the detour design flood is provided for by a low roadway profile that allows overflow without creating excessive velocities or backwater.

19.7.6 Environmental Aspects

Minimum disturbance of the banks and bed of a stream during the construction period will reduce erosion damage to the banks, sedimentation and harm to fish and wildlife. Embankments in or along streams should be constructed of erosion-resistant material and/or protected against erosion to avoid adverse sediment concentrations that contribute to the turbidity of the stream.

Consideration should be given to precluding in-stream operations that would cause turbidity during the spawning season of certain types of fish. Detours and construction roads are other sources of turbidity and should either be constructed at a time that fishery activities will not be disturbed, or provisions should be made to control any harmful effects of erosion. Silts and clays will generally flush out of the substrate over a period of time but sands tend to become embedded. Gravel and rock similar to the gradations found in the existing substrate will do the least damage to the aquatic habitat. The Utah Division of Water Rights is a very good source of information on the presence of fish and the seasons during which protection is necessary.

Pumping of cofferdams and other dewatering operations may have a discharge of unacceptable quality to the receiving stream. Mitigation measures such as settling basins may be necessary if the ecosystem of the stream would be upset by the temporary degradation of water quality.

19.7.7 Stream Restoration

Bridge construction projects often include extensive work in the stream including construction of temporary roadways and channel relocations. The contractor should take sufficient precautions to protect the stream from pollution from fuels, oils, bitumens, calcium chloride or other harmful materials during construction operations. Upon completion of the work, the contractor should repair all portions of the stream that received damage or were affected by the construction activities. The stream should be restored to its preconstruction condition as practicable.

19.7.8 Feedback

Most designers do not have an opportunity to participate in the construction of the projects that they have designed. Design flaws tend to be perpetuated simply because the designer is not informed of the deficiencies. The Department has developed a “Lessons Learned” database to collect information on design and construction flaws, to inform designers and mangers about the flaws. Designers are encouraged to visit construction sites to discuss problems with designs and possible improvements in future designs. This is especially important for major projects like bridge construction. Upon completion of a project, a design critique conducted jointly by designers and field personnel can be a very useful learning experience for both. This critique should include difficulties encountered in the construction and possible design changes to prevent such difficulties in the future. This will also give the designer an opportunity to present why some difficulties in construction are necessary because of specific design considerations.

19.8 OPEN CHANNELS

19.8.1 Introduction

Many of the construction considerations for open channels are the same as for culverts and bridges (e.g., plans, specifications and special provisions; hydrologic information, timing and

scheduling; environmental and ecological aspects; feedback); thus, Sections 19.6 and 19.7 should be reviewed as they relate to open channel construction. The following discussion will concentrate on those construction considerations that are unique to open channels.

The design of permanent diversions or modifications to the stream, including changes in alignment or conveyance, typically include consideration of the existing stream characteristics over a range of flood magnitudes, the class and type of facility involved, and environmental issues such as fish and wildlife habitat. The designer and/or resource management agency may need to be consulted during construction of the stream modifications if there is a change to the design or a problem.

19.8.2 Channel Modification

In designing a permanent modification of a stream/channel, the designer shall consider the following factors:

- the existing stream characteristics over a range of flood magnitudes,
- the class and type of facility involved, and
- environmental issues such as fish and wildlife habitat.

If unexpected conditions at the construction site demand a change to the original channel modification design, the designer should seek approval from regulatory agencies as early as possible. More details on permanent channel modification could be found in Chapters 6 and 7 of Reference *(1)*.

The designer shall also consider the above factors for a temporary modification of the channel (such as toe trench construction for ripraping bridge abutments or piers), but no special permit from the regulatory agency(ies) is required. The temporary modification of the channel has been usually covered in the general permit with the regulatory agency(ies) (e.g., USACE 404 Permit, FEMA permit).

19.8.3 Bank Stabilization

Bank stabilization is an important aspect of open channel construction. Because, in some cases, a considerable length of a stream or channel system may be disturbed by construction, great care should be exercised in scheduling and implementing stabilization measures. Immediately prior to the commencement of construction of bank stabilization measures, the designer should inspect the site to ensure that measures proposed are not inappropriate because of bank movement subsequent to completion of design surveys. Recognizing that an entire reach of stream may require stabilization, highway responsibility may well be much more limited in scope and a total solution not possible.

19.8.4 Excavation

Channel excavation work on some projects may be completed several months before total project completion. The time between completion of channel excavation and total project completion is usually longer when grading and structure projects are separated from the contract for paving or stabilization. During this period, vegetative erosion and control measures are not well established and maintenance to correct erosion and sediment deposition in the newly constructed channels is important to achieving the results intended. The Agency should

provide for maintenance by the contractor during the term of the contract, require interim protective measures and/or advance its own maintenance schedule to assure that minor damage will not develop into major damage that will require costly repairs or replacement when it assumes the permanent maintenance responsibility.

19.8.5 Access

Damaged channels can be both expensive to repair and hazardous to traffic. To facilitate repair and maintenance, channels should be designed recognizing that periodic maintenance, inspection and repair will be required. Where possible, access should be incorporated for personnel and equipment during the construction period and afterward. Consideration should be given to the size and type of equipment that will ordinarily be required in assessing the need for access easements, entrance ramps and gates through right-of-way fences and fee right-of-way.

19.8.6 Temporary Stockpiling of Materials in Regulatory Floodway

The stockpiling of construction materials in a regulatory floodway is usually not encouraged, even if it is only temporary and it has been covered in the permit with the regulatory agencies. Construction materials should be stored outside a regulated floodplain when possible.

Section 60.3(d) of the Code of Federal Regulation (44 CFR , Parts 59-79) of the National Flood Insurance Program (NFIP) prohibits encroachments within the FEMA-adopted regulatory floodway unless it is demonstrated through hydrology and hydraulic analyses that the proposed encroachment will not result in any increase (up to three decimals) in the base flood elevation (BFE) within the community during a base flood (100-yr) discharge.

The designer may satisfy the above request and may obtain FEMA's permission to temporarily stockpile materials in the floodway. In that case, the stockpiling in the floodway should be allowed only during the non-flood season for safety reasons.

19.9 STORM DRAINAGE

19.9.1 Introduction

Many storm drain construction considerations are similar to those encountered in culvert and open channel construction. Thus, Sections 19.6 and 19.8 should be reviewed as they relate to storm drainage construction considerations. It is important to note that the pipe joints for storm drain installations should be thoroughly inspected prior to backfilling. Also, unexpected drainage discharges along the alignment of the storm drain may be encountered during construction and may require special consideration. The following discussion will concentrate on those considerations that are unique to storm drainage systems.

19.9.2 Plan Revisions

Plans for subsurface drains are seldom as complete as those for culverts. The discovery of damaging amounts of groundwater during preliminary materials investigation is difficult. During dry seasons, or following a long, dry cycle, indications of groundwater problems may be missing entirely. However, with the return of a wet season, serious problems may occur if needed subsurface drains are not installed. Installations should be carefully reviewed and plans revised as necessary to fit field conditions in consultation with the designer. It is seldom necessary to

decrease the number of planned subsurface drains; the contrary is usually the case. Also, the location of subsurface and other drains may need to be changed to locate these facilities in stable areas and at low points or other locations where the drainage of surface water can be intercepted and allowed to efficiently enter the storm drain system.

During the clearing and grading operations, groundwater problems may become evident. Swamps, bogs, springs and areas of lush growth are possible indicators of excess groundwater. Fill foundation areas should be inspected minutely before starting embankments. Ravines and draws are especially suspect. As excavation progresses, perched water or various aquifers may be encountered in the area of slopes or at grade.

19.10 "AS-BUILT" PLANS

"As-built" plans serve many functions related to the design and construction process including documentation of:

- the final location of all elements of the drainage system and related facilities;
- any changes that were made in the design during the construction process (e.g., size of facilities, flowline elevations, materials used, addition or elimination of facilities); and
- any variation between the original plans and specifications and the final installed facilities.

The completion of accurate and complete as-built plans can be invaluable in documenting changes that can be incorporated in future designs and to future investigations of the project if problems are encountered or there is some need to analyze the facility's performance. Possible future legal action makes the documentation of as-built plans very important (see Section 19.6.3).

19.11 REFERENCES

(1) AASHTO, *Highway Drainage Guidelines,* Chapters 1-7, Task Force on Hydrology and Hydraulics, 2003.

- Chapter 3, "Erosion and Sediment Control in Highway Construction"
- Chapter 6, "Hydraulic Analysis and Design of Open Channels"
- Chapter 7, "Hydraulic Analysis for the Location and Design of Bridges"
- Chapter 10, "Surface Water Environment"